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ABSTRACT

This study tested the validity of the prevalent assumption that a teacher's understanding of the nature of science, in and of itself, is related to changes in the conceptions of his/her students and identified the classroom dimensions (such as teacher behavior and classroom ecology) significantly related to changes in students' conceptions. Data were obtained from pre- and post-test administrations of the "Nature of Scientific Knowledge Scale" (NSKS) to both teachers and students. Three intensive qualitative field observations in each of 18 biology classrooms yielded 44 variables of teacher behavior and classroom climate. The data collected from the observations were compared with the degree of change (high or low) in teacher and student views as measured on the NSKS. Results indicate that teachers' conceptions of the nature of science are not significantly related to changes in students' conceptions of science. Results also indicate the existence of several common characteristics in classrooms in which students exhibited the largest conceptual changes. For example, problem-solving and frequent, inquiry-oriented questioning typified these classrooms. In addition, students in these classrooms were more attentive and exhibited more participation. (JN)

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DELINEATING CLASSROOM VARIABLES RELATED TO STUDENTS' CONCEPTIONS OF THE NATURE OF SCIENCE

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Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, Louisiana, April 1984.

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Background

The National Science Teachers Association (1982) has recently stated that "scientific literacy for all citizens" is the primary aim for science education in the 1980's. Furthermore, an adequate conception of the nature of scientific knowledge is well recognized as an essential attribute of the scientifically literate individual (Klopfer, 1969; Showalter, 1974; NSTA, 1982).

Research relevant to student conceptions of science has led to the alarming conclusion that science teachers themselves have inadequate conceptions of science (Miller, 1963; Schmidt, 1967). In response, much time and effort has been invested (with little success) to promote more adequate teacher conceptions of science with the anticipation that improved student conceptions would necessarily follow. Clearly, it has been assumed that a significant positive correlation between teachers' and students' conceptions of the nature of science exists. Interestingly, this assumption has remained virtually untested.

It seems clear that if such a relationship does, in fact, exist it must be somehow mediated through varying classroom dimensions (i.e., teacher behaviors, classroom climate). Unfortunately, previous research has not adequately investigated this point.

Purpose

The purpose of this research was twofold:

1. To test the validity of the prevalent assumption that a teacher's understanding of the nature of science, in and of itself, is related to changes in the conceptions of his/her students.

2. To identify the classroom dimensions (i.e., teacher behaviors/classroom ecology) significantly related to changes in students' conceptions.

Subjects

The subjects for this study consisted of 18 senior high school biology teachers and the students from one randomly selected tenth grade New York State Regents Biology class of each teacher. A total of 409 students with a mean of 22.72 per classroom constituted the student cohort. Each classroom was heterogeneous with respect to sex. The students, because they were enrolled in a New York State Regents Biology course, were considered to be of above average ability. It is important to note that the New York State Regents syllabus has as an objective that "students will understand the nature of science" (State Education Department, 1982).

The teacher sample ranged in experience from a minimum of five years to a maximum of 29 years with a mean of 15.83 years of teaching experience. Seven of the teachers were female and 11 were male.

The teachers and students were chosen solely from public senior high schools in Onondaga County, New York. The 18 classrooms studied were distributed among nine schools, with a maximum of three classrooms being chosen in any one particular school. The nine schools represented urban (six classrooms), rural (one classroom), and suburban (11 classrooms) populations. The population of the suburban and rural schools is predominantly Caucasian but heterogeneous with regard to socioeconomic status, while the urban schools are heterogeneous with respect to both ethnicity and socioeconomic status.

Method

This research was primarily exploratory in nature and involved a blend of qualitative and quantitative techniques. The specific approach used was largely derived from the case study approach developed for the Beginning Teacher Evaluation Study (BTES) (Tikunoff, Berliner & Rist, 1975). The purpose of BTES was to identify teacher behaviors and classroom qualities related to the effective teaching of reading and mathematics.

In brief, this study was conducted in five distinct phases. Two phases involved pre- and post-test administrations of the "Nature of Scientific Knowledge Scale" (NSKS) (Rubba, 1976) for all subjects (i.e., teachers and students). The NSKS is purported to be an objective measure of secondary school students' understanding of the nature of scientific knowledge. In addition to an overall scale, the NSKS contains six subscales. Twelve weeks separated the two test administrations. Coefficient alpha reliabilities (Nunnally, 1967) were calculated for both test administrations and may be found in Table I of the results section.

Between pre- and post-testing the researcher made a total of three intensive qualitative field observations in each of the eighteen biology classrooms. During each classroom observation the author attempted to record all teacher and student verbalizations, notes written on on the blackboard, assignments, exercises, overhead transparencies, mannerisms, nonverbal cues, and classroom physical plan. In addition, copies of all handouts were obtained and included with the notes taken during each observation. All classroom observations were completed within eight weeks.

Changes in students' conceptions from pre- to post-test were computed and standardized. These standardized student score changes were used to test the validity of the prevalent assumption that changes in students' conceptions of science are positively correlated with the conceptions of their teachers. Therefore the null form of the following hypothesis was tested using the NSKS overall scores and a .05 level of significance:

H_1: There will exist a significant positive correlation between a teacher's conception of the nature of science and changes in his/her students' conceptions of the nature of science.

Since both pre- and posttest scores for each teacher were known, the null hypothesis was tested once using each. This procedure helped control for the possibility that the teachers' conceptions would differ during their instruction from conceptions held prior to the observed instructional period.

The student score changes were also used for the rank ordering of the magnitude and direction of students' conceptual changes by class. This allowed categorization of teachers/classrooms on the basis of exhibited differential changes in students' conceptions of the nature of science. Those six teachers/classrooms exhibiting the largest change toward a teacher's viewpoint were categorized as "high" and those six exhibiting the smallest change (minimal positive change or negative changes) were classified as "low." The six teachers/classrooms remaining were categorized as "medium." This categorization of teachers/classrooms was performed for the NSKS overall and the six subscales. It is important to note that a particular teacher/classroom may be considered "high" with respect to one subscale while being considered "low" with respect to another subscale.

The researcher systematically compared the qualitative field notes of "high" and "low" teachers/classrooms in order to derive a list of classroom variables which appeared to differentiate in quality or quantity between the two teacher/classroom categories. The elimination of redundancies and the collapsing of many oppositions into single variable continuums reduced the original list of 89 variables to a more manageable list of 44 discriminating variables. A complete list of these variables with definitions is found in Table III. The researcher was unaware of the specific group memberships ("high" or "low") of the teachers/classrooms during the derivation of variables.

Finally, the 44 qualitative variables were quantitatively tested to ascertain whether they statistically discriminated between the teachers/classrooms categorized as "high" and those categorized as "low." Sixteen independent "raters" with experience in the study of teaching, science education, and/or science content were used for quantitative analysis of classroom variables. After inter-rater reliability was achieved (i.e., $\geq .75$), each rater was asked to compare paired data sets (i.e., one from the "high" and one from the "low" categories) as they had done during the reliability check. That is, the raters were asked to compare teachers/classrooms using the following comparison instrument (Figure 1).

Figure 1. Classroom Comparison Instrument.

Name of Rater _____ Date _____

Classrooms Compared _____ X _____

Classroom Variables

1. _____ _|__|__|__|__|__|__|__|__|__|_
Less <----------> More

.
.
etc.

Raters were asked to place the number of each teacher/classroom on the rating scale so that it best represented which teacher/classroom evidenced "more" of a given classroom variable and which evidenced "less." For logistical reasons only two of the seven NSKS scales (i.e., Overall and Developmental [Tentative/Revisionary]) were quantitatively evaluated. The data produced by rater comparisons were perceived as a series of binomial variables. Therefore, the discriminatory significance of each classroom variable could be tested using a binomial test as described by Kerlinger (1965, pp. 260-263).

The results of these analyses served as an independent quantitative test regarding which of the qualitatively derived classroom variables were significantly related to changes in students' conceptions of the nature of science. The null forms of the following research hypotheses were tested using a non-directional binomial test with a .05 level of significance:

H_2: There will exist a significant difference in the presence of a particular classroom variable between "high" teachers/classrooms on the overall nature of science and "low" teachers/classrooms on the same.

H_3: There will exist a significant difference in the presence of a particular classroom variable between "high" teachers/classrooms on the developmental nature of science and "low" teachers/classrooms on the same.

Results

The primary results have been organized with respect to phase sequence.

NSKS Test Administration

Research Phases One and Three consisted of NSKS pretesting and posttesting of both students and teachers and

subsequent testing of the relationship between teachers' and students' conceptions of science. Since the strength of this research rests heavily upon the "trustworthiness" of the NSKS instrument, establishing reliability for each test administration was essential. Pre- and posttest reliabilities are presented in Table I.

TABLE I

Coefficient Alpha Reliabilities (Nunnally, 1967) for NSKS Subscales and Overall Score

	Pretest	
Subscale/Scale	Regents Biology Students n = 409	Teachers n = 18
Amoral	.704	.872
Creative	.768	.714
Developmental	.714	.764
Parsimonious	.661	.698
Testable	.722	.815
Unified	.706	.728
Overall	.771	.925

	Posttest	
Subscale/Scale	Regents Biology Students n = 409	Teachers n = 18
Amoral	.765	.841
Creative	.801	.736
Developmental	.742	.728
Parsimonious	.703	.720
Testable	.768	.845
Unified	.739	.747
Overall	.838	.916

Teachers' NSKS scores and the standardized student change scores were used to test the null form of the following hypothesis:

H_1: $\rho > 0$
$\alpha = .05$

The hypothesis was tested once using teachers' pretest scores and once using the posttest scores. Table II indicates the results of the two tests of correlational significance.

TABLE II

Correlation Between Teachers' NSKS Overall Scores and Students' Standardized Change

Teachers' NSKS Overall Score	df (n-2)	Pearson Product Moment (r)	(p)
Pretest	16	.305	$p > .05$
Posttest	16	.224	$p > .05$

In each case reported in Table II the correlation was not found to be significant and the null hypothesis could not be rejected. Therefore, the data do not support the contention that a teacher's conception of the nature of science, in and of itself, is positively correlated with changes in his/her students' conceptions of science. This finding is contrary to a long-lived, but virtually untested, assumption which underlies research concerned with the nature of science.

Phase Four: Derivation of Classroom Variables

The lack of a significant correlation between a teacher's conception of the nature of science and changes in his/her students on this variable provided additional support for the importance of the major focus of this research -- identification of those classroom variables related to changes in students' conceptions of science. After all, students do not simply change their conceptions of the nature of science as a result of exposure to a

teacher with a different conception. Teacher behavior and classroom ecology must mediate such a change. Qualitative comparisons between contrasting data sets ("high" vs. "low" teachers/classrooms) as described in the method section of this paper yielded the 44 classroom variables presented in Table III. The variable definitions are necessarily summarized from those actually given to the raters. A complete copy of the "Rater Manual" can be obtained from the author.

The discriminatory ability of each classroom variable was statistically tested using the procedure described in the method section of this paper. Tables IV and V illustrate the frequency deviations (and associated probabilities) for each classroom variable on each of the two scales. Those variables with an associated probability of less than .05 are considered to be significant.

TABLE III

Derived Classroom Variables

1. ANECDOTAL (TG) - Teacher uses (does not use) stories, analogies & examples to illustrate concepts
2. DYNAMIC (TG) - Teacher's presentation is (is not) energetic & theatrical with good voice inflections
3. ROTE MEMORY/RECALL (TG) - Material is (is not) presented at the factual or knowledge level
4. LECTURING (TG) - Teacher talk does (does not) monopolize class time with little student involvement
5. FREQUENT QUESTIONING (TG) - Teacher asks (does not ask) frequent questions
6. FRAGMENTED (TG) - Teacher's presentation is (is not) "free-flowing" and logically sequential
7. HIGHER LEVEL QUESTIONS (TG) - Higher level questions (Bloom's Taxonomy) are (are not) used frequently
8. INSTRUCTIONAL DIGRESSION (TG) - Topics peripherally related to main concept are (are not) pursued
9. PACING (TG) - Teacher does (does not) continually assess class understanding and adjusts pace accordingly
10. PERIODIC REVIEW (TG) - Class time is (is not) used to review/drill students on previously presented material
11. PREDICTABLE (TG) - Mode of presentation is (is not) inflexible irrespective of content
12. PROBLEM SOLVING (TG) - Open ended questions and/or discrepant events are (are not) used
13. RECEPTIVE (TG) - Teacher is (is not) receptive to student-initiated questions
14. RUSHING (TG) - Teacher does (does not) attempt to quickly cover a predetermined amount of material
15. SEAT WORK (TG) - Class time is (is not) allocated for written exercises or textbook reading
16. PROBING (TG) - Follow-up questions to student responses are (are not) used
17. SUPPORTIVE (TG) - Positive encouragement is (is not) often used
18. HUMOR (TG) - Teacher does (does not) interject jokes and/or humorous histrionics during instructional presentation
19. VARIETY OF MEDIA (TG) - Diverse instructional materials are (are not) used in presentation of content
20. AMORAL (TC) - Scientific knowledge is (is not) presented as amoral
21. ANTHROPOMORPHIC LANGUAGE (TC) - Anthropomorphic language is (is not) used and accepted by the teacher
22. ARBITRARY CONSTRUCTS (TC) - Arbitrary nature and utility of scientific constructs are (are not) stressed
23. CREATIVITY (TC) - Scientific knowledge is (is not) presented as a product of human imagination and creativity
24. DEVELOPMENTAL (TC) - Scientific knowledge is (is not) presented as being tentative
25. FALLIBILITY (TC) - Teacher does (does not) admit uncertainty with respect to content
26. LANGUAGE ACCURACY (TC) - Exact definitions of terminology are (are not) stressed
27. MISINFORMATION (TC) - Teacher does (does not) present misinformation
28. MORAL/ETHICAL IMPLICATIONS (TC) - Moral & ethical implications created by science are (are not) emphasized

29. PARSIMONY (TC) - Scientific knowledge is (is not) presented as being comprehensive as opposed to specific
30. QUANTITY OF MATERIAL (TC) - An inordinately large amount of subject matter is (is not) presented
31. RELEVANCY (TC) - Practical nature of subject matter is (is not) emphasized
32. SUPERFICIALITY (TC) - Teacher's explanations of phenomena are correct but inadequate
33. TESTABLE (TC) - The importance of empirical validation of subject matter is (is not) stressed
34. UNIFIED (TC) - The interrelationship of various science disciplines is (is not) emphasized
35. DEMEANOR (TA) - The teacher is (is not) pleasant
36. IMPERSONAL (TA) - The teacher does (does not) attempt to socialize with students before or after class
37. NON-INSTRUCTIONAL DIGRESSIONS (TA) - The teacher does (does not) tell stories totally unrelated to content being presented
38. ACTIVE ENGAGEMENT (S) - Students are (are not) actually participating in lesson
39. ATTENTIVE (S) - Students are (are not) on task for most of the class period
40. UNSOLICITED QUESTIONS (S) - Students ask (do not ask) unsolicited questions
41. DISCIPLINE (C) - Classroom atmosphere is (is not) highly structured and discipline oriented
42. DOWN TIME (C) - Class time is (is not) often characterized by students waiting for next activity
43. LOW ANXIETY (C) - Classroom atmosphere is (is not) comfortable with little anxiety
44. RAPPORT (C) - Teacher and students do (do not) socialize and interact in a friendly manner

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Variable categories: TG: Teacher's general instructional approach; TC: Teacher's content-specific characteristics; TA: Teacher's non-instructional characteristics; S: Student characteristics; C: Classroom atmosphere.

TABLE IV

Rating Results on Paired Comparisons for the NSKS Overall Scale

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Classroom Variable	"High" teacher/ classroom rated as evidencing more	"Low" teacher/ classroom rated as evidencing more	Probability (p)
Teacher's General Instructional Approach			
1. Anecdotal	23	1	< .0001
2. Dynamic	22	2	< .0001
3. Emphasis on rote mem/recall	4	20	.0014
4. Extended lecturing	4	20	.0014
5. Frequent questioning	20	4	.0014
6. Fragmented	9	15	.3070
7. Higher cognitive level quest	23	1	< .0001
8. Instructional digression	22	2	< .0001
9. Pacing	19	5	.0064
10. Periodic review	13	11	.8384
11. Predictable	4	20	.0014
12. Problem solving	23	1	< .0001
13. Receptive to unsolicited quest	22	2	< .0001
14. Rushing	13	11	.8384
15. Seat work	6	18	.0224
16. Sequential probing	23	1	< .0001
17. Supportive	22	2	< .0001
18. Use of humor	19	5	.0064
19. Variety of instruc media	20	4	.0014
Teacher's Content-Specific Characteristics			
20. Amoral	9	15	.3070
21. Anthropomorphic	12	12	> .9999
22. Arbitrary constructs	18	6	.0224
23. Creativity	17	7	.0636
24. Developmental	19	5	.0064
25. Fallibility	22	2	< .0001
26. Language accuracy	22	2	< .0001
27. Misinformation	3	21	< .0002
28. Moral & ethical implications	20	4	.0014
29. Parsimony	17	7	.0636
30. Quantity of material	18	6	.0224
31. Relevancy	20	4	.0014
32. Superficiality	5	19	.0064
33. Testable	23	1	< .0001
34. Unified	16	8	.1512
Teacher's Non-Instructional Characteristics/Attitudes			
35. Demeanor	21	3	.0002
36. Impersonal	3	21	.0002
37. Non-instruc digression	18	6	.0224
Student Characteristics			
38. Active engagement	23	1	< .0001
39. Attentive	21	3	.0002
40. Unsolicited questioning	21	3	.0002
Classroom Atmosphere			
41. Discipline	17	7	.0636
42. Down time	6	18	.0224
43. Low anxiety	21	3	.0002
44. Rapport	21	3	.0002

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TABLE V

Rating Results on Paired Comparisons for the NSKS Developmental Subscale

Classroom Variable	"High" teacher/ classroom rated as evidencing more	"Low" teacher/ classroom rated as evidencing more	Probability (p)
Teacher's General Instructional Approach			
1. Anecdotal	21	3	.0002
2. Dynamic	19	5	.0064
3. Emphasis on rote mem/recall	3	21	.0002
4. Extended lecturing	9	15	.3070
5. Frequent questioning	18	6	.0224
6. Fragmented	9	15	.3070
7. Higher cognitive level quest	22	2	< .0001
8. Instructional digression	21	3	.0002
9. Pacing	14	10	.5408
10. Periodic review	14	10	.5408
11. Predictable	8	16	.1512
12. Problem solving	22	2	< .0001
13. Receptive to unsolicited ques	19	5	.0064
14. Rushing	3	21	.0002
15. Seat work	6	18	.0224
16. Sequential probing	21	3	.0002
17. Supportive	20	4	.0014
18. Use of humor	19	5	.0064
19. Variety of instruc media	22	2	< .0001
Teacher's Content-Specific Characteristics			
20. Amoral	13	11	.8384
21. Anthropomorphic	12	12	> .9999
22. Arbitrary constructs	14	10	.5408
23. Creativity	22	2	< .0001
24. Developmental	21	3	.0002
25. Fallibility	17	7	.0636
26. Language accuracy	20	4	.0014
27. Misinformation	7	17	.0636
28. Moral & ethical implications	18	6	.0224
29. Parsimony	14	10	.5408
30. Quantity of material	8	16	.1512
31. Relevancy	20	4	.0014
32. Superficiality	9	15	.3070
33. Testable	22	2	< .0001
34. Unified	15	9	.3070
Teacher's Non-Instructional Characteristics/Attitudes			
35. Demeanor	22	2	< .0001
36. Impersonal	5	19	.0064
37. Non-instruc digression	14	10	.5408
Student Characteristics			
38. Active engagement	20	4	.0014
39. Attentive	19	5	.0064
40. Unsolicited questioning	20	4	.0014
Classroom Atmosphere			
41. Discipline	11	13	.8384
42. Down time	9	15	.3070
43. Low anxiety	21	3	.0002
44. Rapport	19	5	.0064

Discussion

The literature reviewed for this research clearly established science educators' willingness to accept the assumption that teacher conceptions of the nature of science are significantly related to changes in students' conceptions of science. However, the data here do not support such an assumption. The lack of a significant correlation might initially leave educators skeptical. After all, the rather intuitive notion that a teacher cannot teach what he/she does not know is universally accepted. Indeed, the findings here are not contrary to such a notion and the author does not wish to contend that such a view is incorrect. The lack of a significant relationship between teacher conceptions and changes in students' conceptions simply indicates that a teacher's conceptions of science are not of sole or necessarily primary importance with respect to associated student changes. Since students do not learn by mere physical exposure to a teacher, their changes in viewpoint must, in part, be mediated by teacher behaviors/classroom ecology. From this perspective, the findings discussed, although contrary to prior belief, are not very surprising. One would expect a moderate correlation which would most likely reflect the imperative that a teacher understand what he or she is teaching. However, the lack of statistical significance of this association further emphasizes the importance of those classroom variables which must mediate, in some manner, the observed conceptual changes of the students. The results here remind us that no two teachers are exactly the same in their instructional approach, even if they are teaching precisely the same material. Such a lesson was no better illustrated than by science educators' experience with the evaluation of the post-Sputnik curricula. In short, the data indicate that beyond some level of knowledge or understanding, a teacher's viewpoints are not significantly related to changes in students' viewpoints.

The major portion of this research was designed to identify those classroom variables which are significant to the communication of the nature of science to students. Of course, classrooms, teachers, and students are complex and dynamic. There is a constant interaction among the three. Therefore, the significant variables to be discussed must be considered in context. No variable occurs in a vacuum or exerts an independent influence.

Generic Classroom Variables

The majority of significant classroom variables were considered to be generic in the sense that they statistically discriminated on both the Overall NSKS and the Developmental subscale. Twenty-five of the original 44 classroom variables were considered to be generic.

The teachers/classrooms in the "high" group were typically more warm and supportive than those of the "low" group. The telling of Anecdotes (1), Use of Humor (18), and Instructional Digressions (8) used by teachers in the "high"

group appeared to create a warm, friendly atmosphere. In addition, the teachers of the "high" group were open to student input, as evidenced by the importance of the Supportive (17) and Receptive to Unsolicited Questions (13) variables. Although it is easy to see why a warm and supportive atmosphere would be desirable in any classroom, such does not necessarily contribute to learning and student change. Students must become excited about the material being presented. Their interest and curiosity must be piqued, for a warm and supportive classroom might simply represent a non-threatening one in which the student feels no need to work. The Dynamic (2) nature of the teachers' presentations and the use of a Variety of Instructional Media (19) seemed to have accomplished this task. Furthermore, the related variables of Emphasis on Rote Memory/Recall (3) and increased Seat Work (15) were more common to the "low" group. Completion of worksheets and handouts coupled with major emphasis on memorization of "facts" would certainly detract from the "high-energy" atmosphere created by a dynamic teacher who uses multi-media presentations.

One does not need to be an educator to realize that the variables discussed thus far are desirable but do not necessarily lead to changing students' conceptions of the nature of science. The author prefers to consider such variables as prerequisite classroom dimensions, and does not wish to imply that these variables are sufficient, in and of themselves, with respect to promoting changes in students' students' conceptions of science.

The questioning variables tend to bridge the subcategories of prerequisite and content-oriented (i.e., specifically related to the nature of science) classroom dimensions. Teachers in the "high" group tended to ask questions more frequently. However, the nature of these Frequent Questions (54) is quite important. The questions tended to be of a Higher Cognitive Level (7) and Problem Solving (12) in nature. Consistent with the problem-solving mode of the "high" group, the teachers of these classrooms Sequentially Probed (16) student responses. When one views questioning as a prerequisite classroom dimension its beneficial effects on student involvement and attention are obvious. However, Frequent Questions (5), Higher Cognitive Level Questions (7), Problem Solving (2), and Sequential Probing (16) are all related to the more general classroom dimension of frequent teacher-student interactions which cause students to think about (and not just memorize) subject matter. The importance of such a classroom atmosphere is related to the specific instructional situation to which it often leads. In short, an analysis of the actual interactive sequences recorded in the ethnographic field notes revealed numerous instances in which such interactions led to discussions related to one or more of the NSKS subscales.

Teachers of the "high" classrooms also related content to the students' personal lives more frequently than those of the "low" group as evidenced by the significance of Moral and Ethical Implications (21) and Relevancy (31). Presenting material in a relevant fashion has long been considered a hallmark of "good teaching" and its probable function as a prerequisite classroom dimension is clear. However, analysis of the field notes revealed that each of these variables was manifest in classroom discourse as a discussion of the positive and negative attributes of particular scientific knowledge. Thus, their relationship to the Amoral subscale (and necessarily the Overall scale) is direct. Since Developmental (24) and Testable (33) are directly linked to NSKS subscales, their more common occurrence in the "high" group is easily understood.

Finally, variables such as Demeanor (35), Impersonal (36), Active Engagement (38), Attentive (39), Unsolicited Questions (41), Low Anxiety (43) and Rapport (44) must be considered as prerequisite variables which are consistent with the findings concerning previously mentioned prerequisite variables (e.g., Dynamic, Supportive, Receptiveness, etc.).

Scale-Specific Classroom Variables

Certain variables were significant in discriminating between "high" and "low" groups on one scale but not on the other and are, therefore, scale-specific by nature. Twelve variables appeared to be scale-specific. The teachers/classrooms of the "high" group on the Overall scale appeared to stress content (quantity and accuracy) to a greater degree than members of the "low" group. In contrast, content depth and quantity were not significant in differentiating between of the "high" and "low" groups on the Developmental subscale. In fact, the Quantity of Material (30) variable showed a reversed direction of comparative frequencies, with Quantity of Material being more common to the "low" group (although not significantly so) on the Developmental subscale.

Only two scale-specific variables were found for the Developmental subscale [i.e., Rushing (14) and Creativity (23)]. The relationship of Creativity (23) to students' viewpoints on the tentative or absolute nature of scientific knowledge is clear. Rushing (14) was more common to the "low" group on the Developmental subscale. This meant that the teachers of the "high" group tended to pay more attention to the complexity of subject matter being presented and did not continue their presentation without such regard. Certainly, such a variable would not be conducive to instruction and one would not expect it to be common to members of the "high" group.

Although one must be cautious not to make causational

statements, there appear to be some common characteristics of the classrooms in which students exhibited the largest conceptual changes. In general (i.e., irrespective of NSKS scale), "successful" classrooms were more often typified by frequent, inquiry oriented questioning. Problem solving and teacher-student interactions were also more common in the "successful" classrooms. The teachers of such classrooms were more dynamic, pleasant, and the use of humor and anecdotes to aid instruction was more commonly exhibited. Alternatively, seat work and emphasis on rote memory/recall were less typical in these classrooms. Such an environment provided the milieu for the successful communication of the teachers' viewpoints on the nature of scientific knowledge. Specifically, more reference to the developmental, testable, and moral and ethical aspects of scientific knowledge was typical of the "successful" classrooms. Finally, as might be expected, the students of the "successful" classrooms were more attentive and exhibited more active participation. Overall, the classrooms exhibiting the largest conceptual changes were more pleasant, supportive, and on-task, with students expected to think analytically about subject matter presented. The most obvious differences between those variables significant to each individual NSKS scale investigated were related to the subject matter presented. That is, depth, breadth, and accuracy of subject matter were significant to the "successful" teachers/classrooms of the Overall scale but not to those of the Developmental scale.

Implications

The insignificant relationship between teachers' conceptions of science and changes in students' viewpoints has clearly placed emphasis on the importance of a teacher's classroom behavior and the classroom atmosphere he/she establishes. Although teachers have been berated in the past (Miller, 1963) for failure to promote adequate student conceptions of science and are constantly being strongly urged to correct the situation (NSTA, 1982), they have not been offered any definitive advice on how to accomplish such an important goal. Given the exploratory design used here the variables elucidated are significant but tentatively so. In short, each variable serves as an hypothesis which needs to be tested using a structured observational coding system. However, in light of recent research findings the author is confident in the accuracy of the findings explicated here. Using an experimental design, Haukoos and Penick (1983) investigated the influence of classroom climate on science process and content achievement. In their study, the "discovery classroom climate" was found to best facilitate gains in students' knowledge of the nature of science as measured by the Science Process Inventory (Welch, 1967). Of major importance here is that their description of the "discovery" classroom is consistent with that of the "high" teachers/classrooms in this study.

One implication of this research is rather disturbing. The various aspects of the nature of scientific knowledge are clearly abstract in character. Soar and Soar (1972) have previously noted that higher amounts of teacher direction, control, and narrow subject matter focus have a destructive effect on students' complex-abstract growth. In short, they found that increased drill and emphasis on lower-level understandings are best suited for simple-concrete student outcomes and the results here seem to be consistent with such a contention. Unfortunately, the nationally popular "back to basics" movement in the sciences stresses increased rote memory and recall of scientific concepts, principles, and definitions. Since administrators often pay or evaluate teachers according to the achievement of their pupils on Regents examinations or standardized tests emphasizing "fact recall," a destructive irony beecomes evident. Science teachers are being urged, in part, to promote gains in students' "complex-abstract" growth and yet are being evaluated on measures of "simple-concrete" growth. Since apparently different teaching techniques are optimal for each general student outcome, the plea for increased student scientific literacy may be asking for the completion of an impossible task. It appears that a more cohesive approach to the goals and evaluation of science education must be developed. Perhaps a more balanced treatment of "factual" content and philosophy of science is needed in both curriculum development and instruments of summative evaluation.

References

Haukoos, G. D., & Penick, J. A. The influence of classroom climate on science process and content achievement of community college students. Journal of Research in Science Teaching, 1983, 20(7), 629-637.

Kerlinger, F. N. Foundations of behavioral research: Educational and psychological inquiry. New York: Holt, Rinehart and Winston, 1965.

Klopfer, L. The teaching of science and the history of science. Journal of Research in Science Teaching, 1969, 6, 87-95.

Miller, P. E. A comparison of the abilities of secondary teachers and students of biology to understand science. Iowa Academy of Science, 1963, 70, 510-513.

National Science Teachers Association. Science--technology-society: Science education for the 1980's. Washington, D.C.: National Science Teachers Association, 1982.

Nunnally, J. C. Psychometric theory. New York: McGraw-Hill, 1967.

Rubba, P. A. Nature of scientific knowledge scale. School of Education, Indiana University, Bloomington, Indiana, 1976.

Schmidt, D. J. Test on understanding science: A comparison among school groups. Journal of Research in Science Teaching, 1967, 4, 365-366.

Showalter, V. M. What is unified science education? Program objectives and scientific literacy. Prism II, 1974, 2, 3-4.

Soar, R. S., & Soar, R. An empirical analysis of selected Follow Through programs: An example of a process approach to evaluation. In I. Gordon (Ed.), Early childhood education (71st Yearbook, National Society for the Study of Education). Chicago: University of Chicago Press, 1972.

State Education Department. Regents biology syllabus. Albany, N.Y.: The University of the State of New York, 1982.

Tikunoff, W., Berliner, D., & Rist, R. Beginning teacher evaluation study, Technical Report No. 75-10-5. San Francisco: Far West Laboratory for Educational Research and Development, 1975.

Welch, W. W. Science process inventory. Cambridge, Mass.: Harvard Physics Project, 1967.